

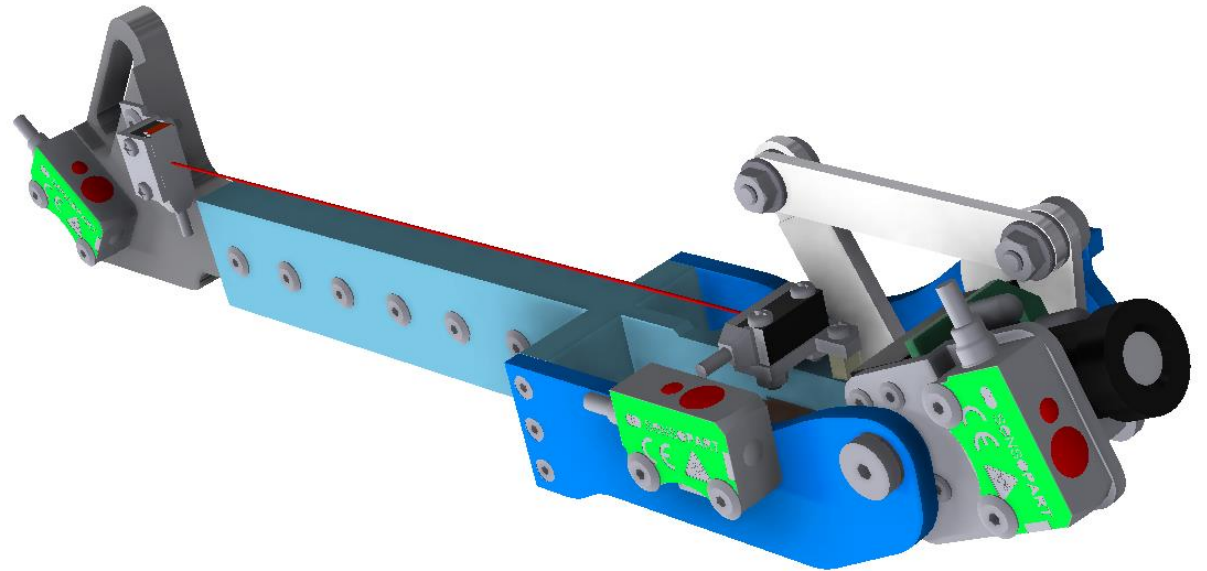
Mechatronic Design for a Novel RF Cavity Visual Inspection System

MRO Technical Meeting


Thursday 09/04/2020

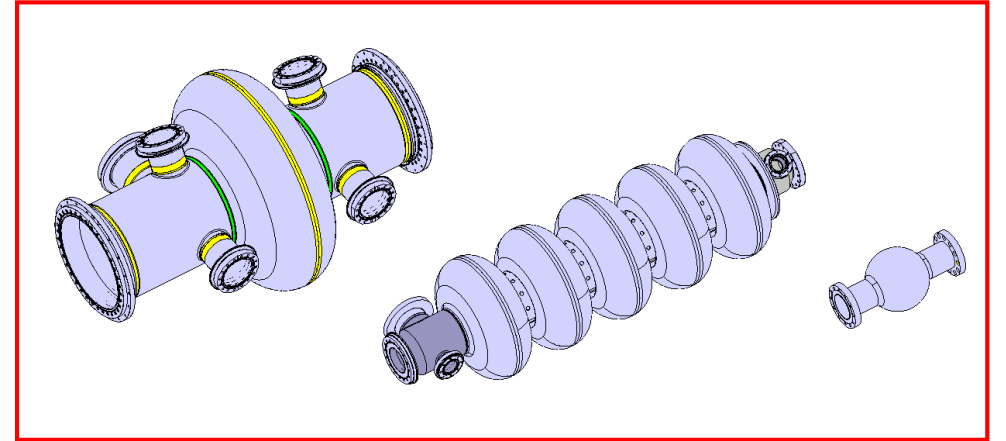
Fabrizio Pirozzi

Master's degree in Mechanical Engineering
University of Naples Federico II

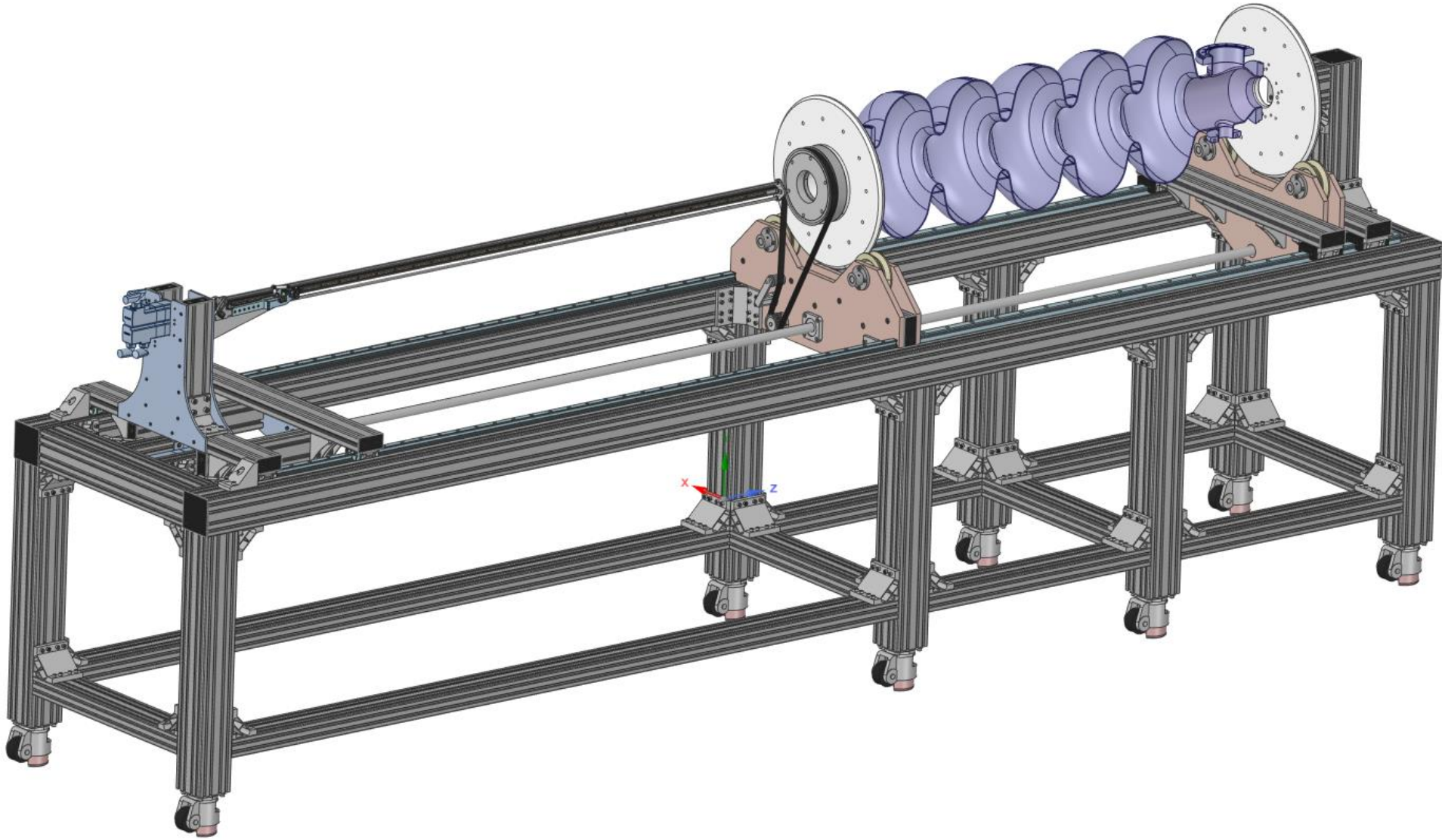


System requirements

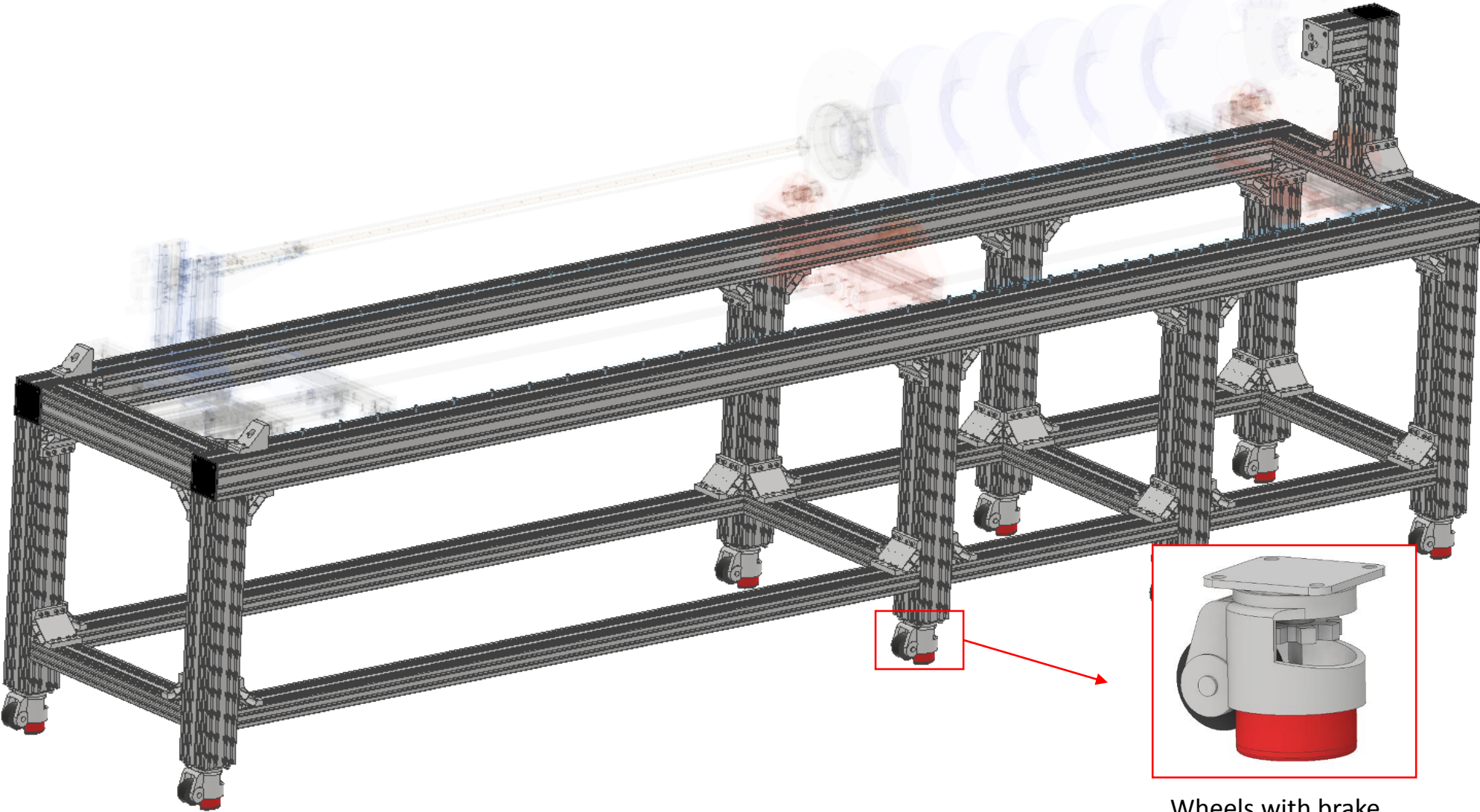
- Detect and locate defects of 10 μm (pits, bumps, cracks, scratches, etc.)
- Allow for inspection of entire internal surface
- Accommodate all cell-cavity types foreseen in RF-SRF 
- Fast operation and during night to minimize temperature variations
- Avoid any collision with RF internal surface
- Repeatability before and after power cycle



Proposed Solution

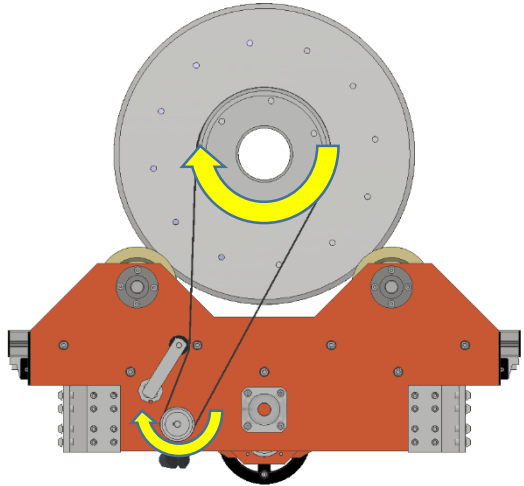
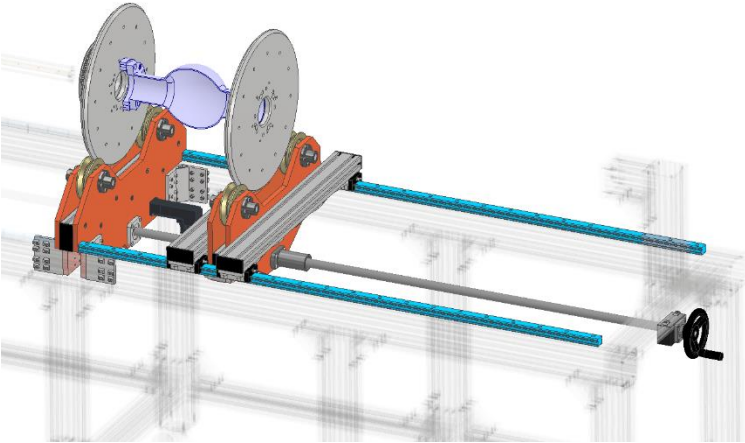
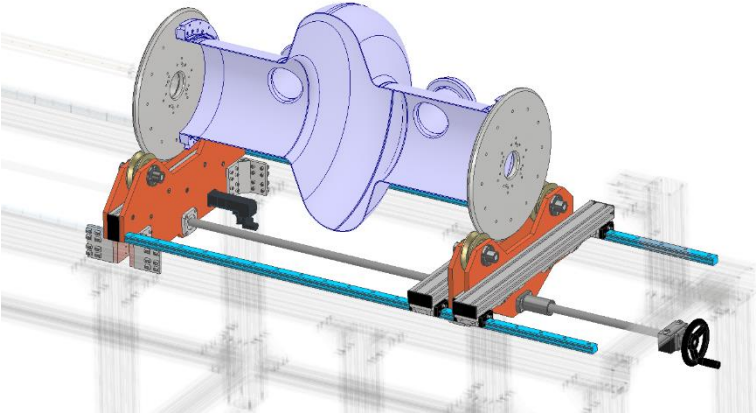
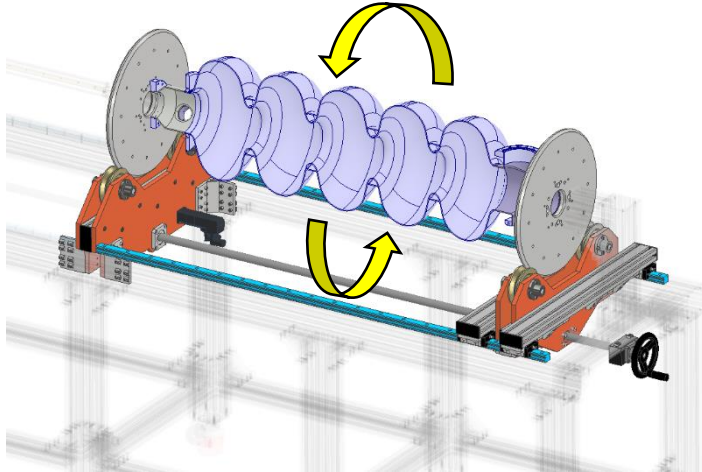
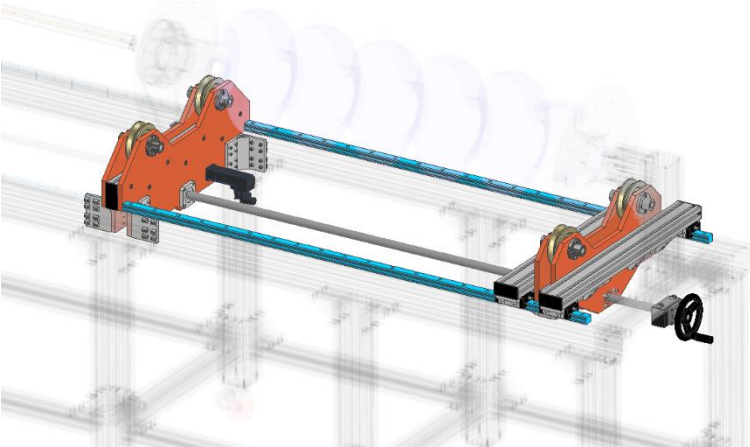
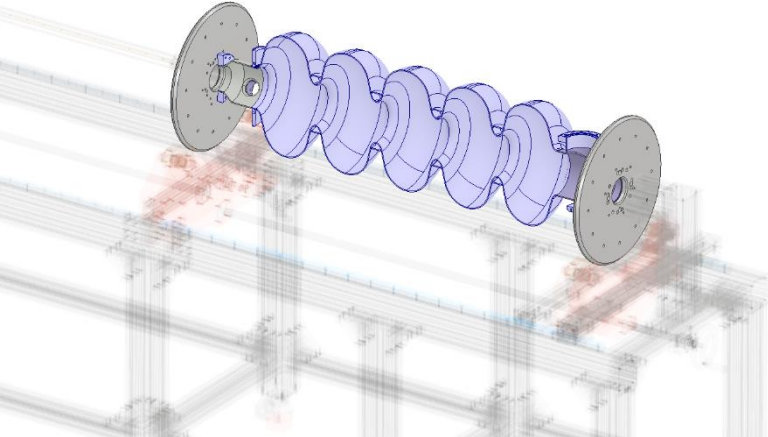


Aluminum frame

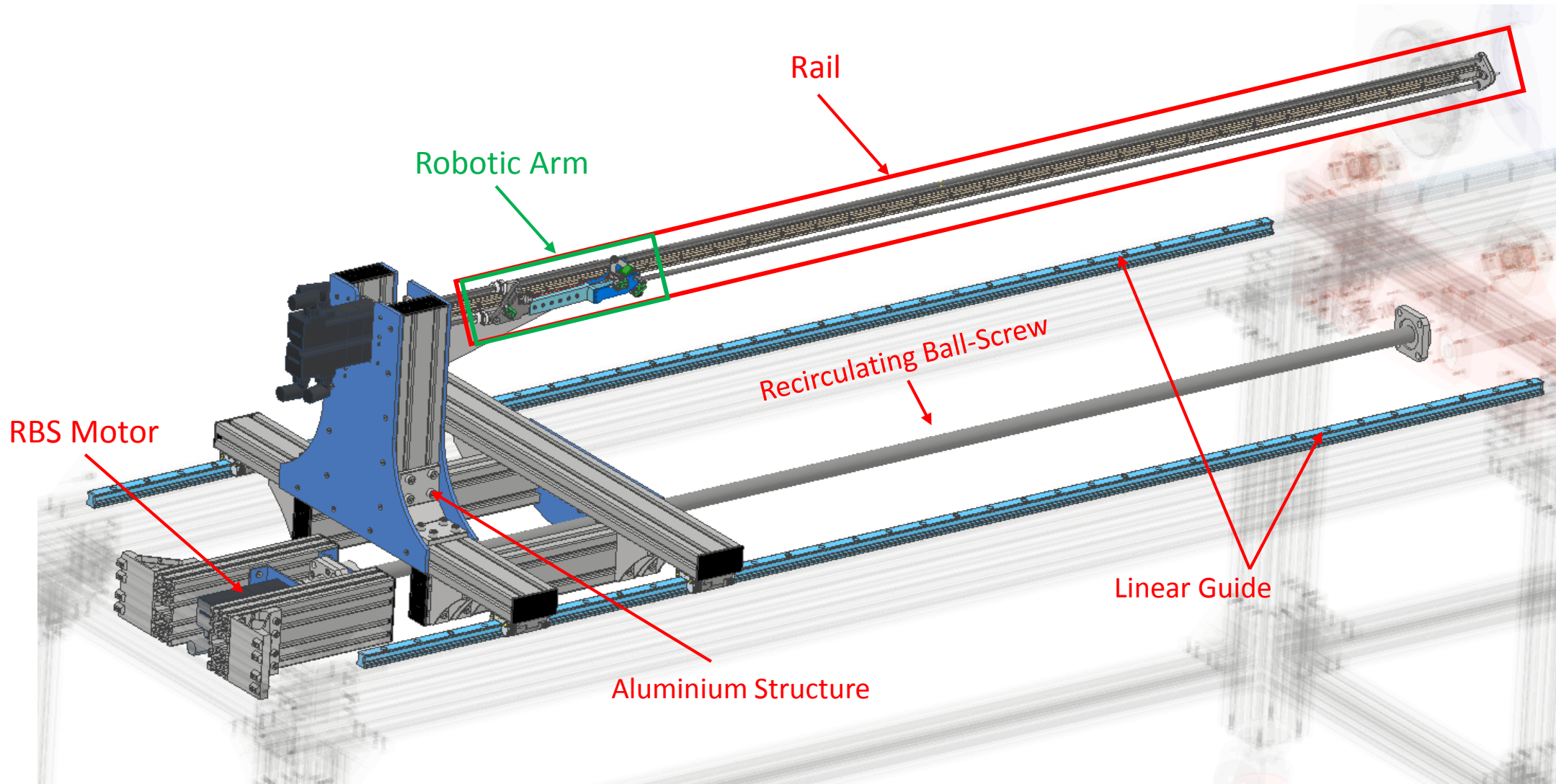


Wheels with brake

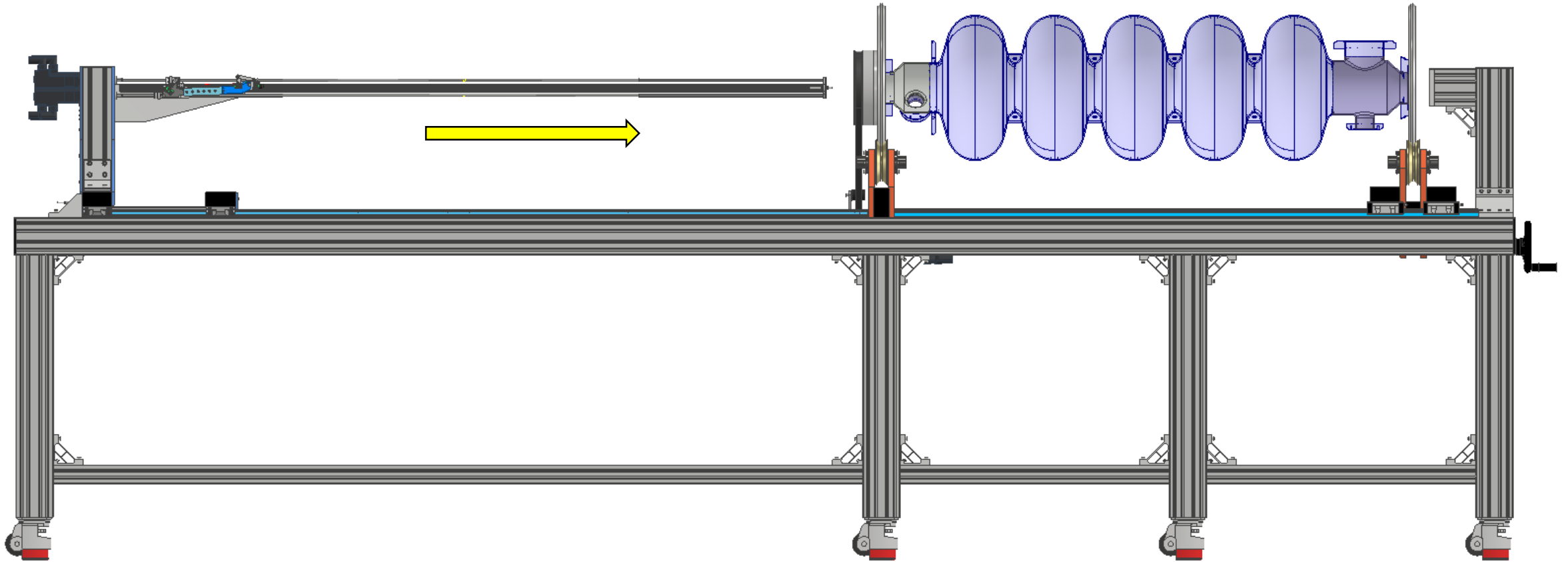
Cavity Support and Handling System



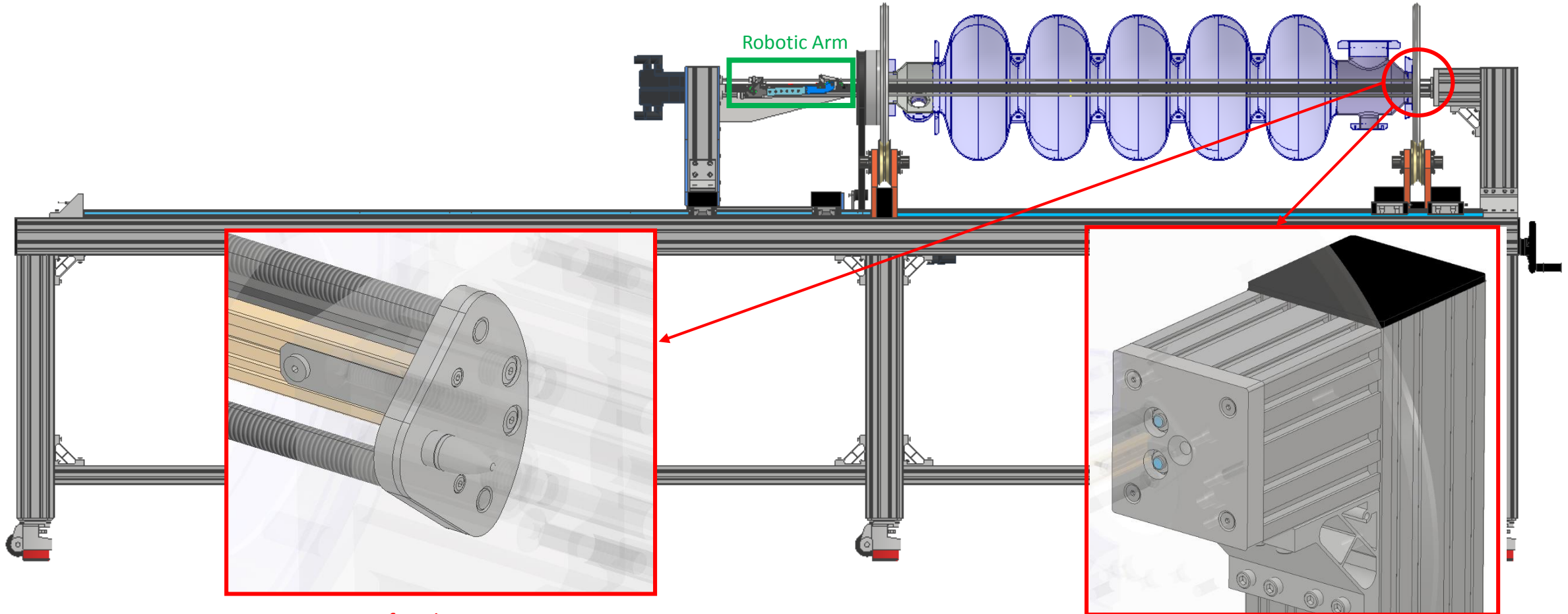
Rail Support and Handling Structure



Rail Support and Handling Structure → Rail Motion → Rail out of the cavity



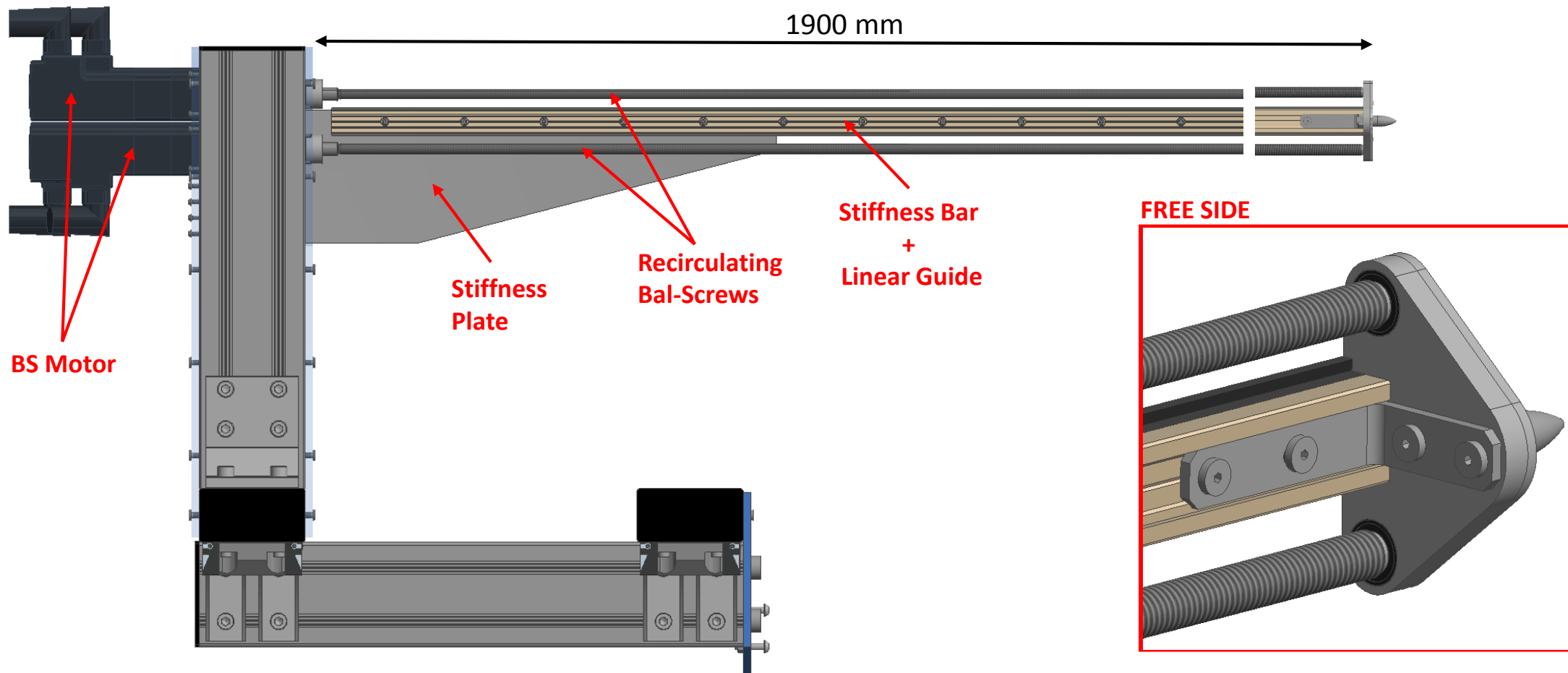
Rail Support and Handling Structure → Rail Motion → Rail inserted into the cavity



Tip for alignment

Limit Switch: mechanical limits + inductive sensor

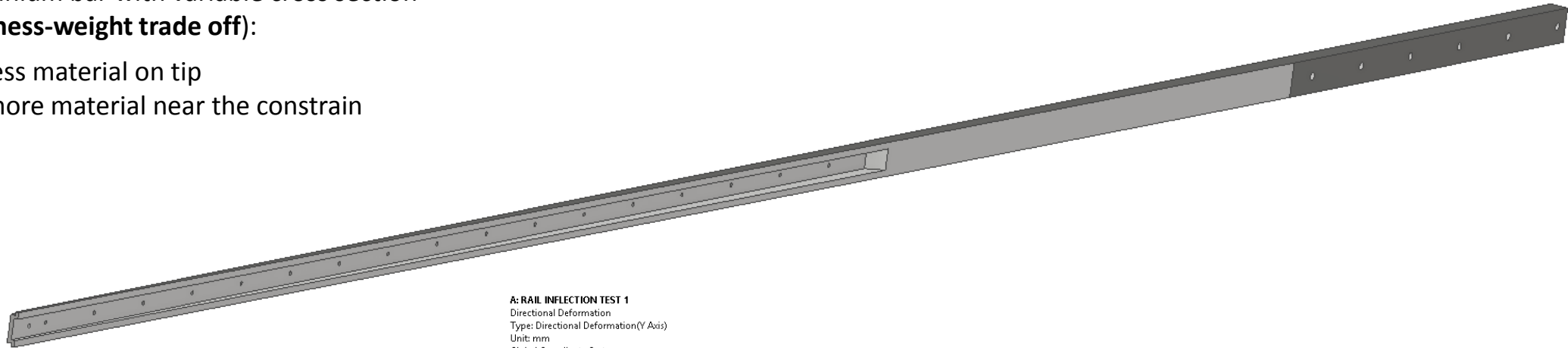
Rail Support and Handling Structure → Rail



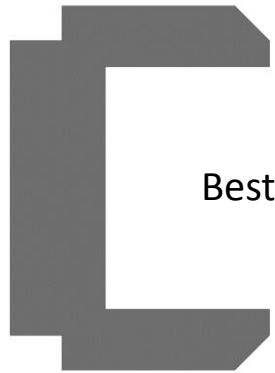
Rail Support and Handling Structure → Rail

Aluminium bar with variable cross section
(stiffness-weight trade off):

- less material on tip
- more material near the constrain

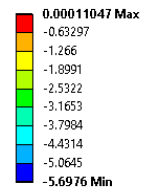


Constant C cross section

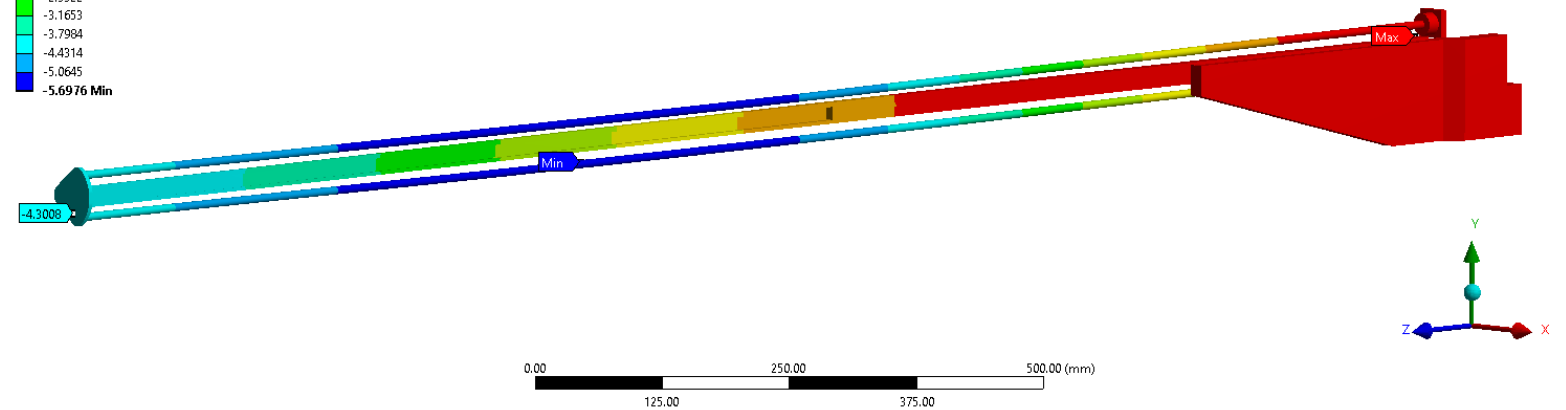


Best results: 6 mm

A: RAIL INFLECTION TEST 1
Directional Deformation
Type: Directional Deformation(Y Axis)
Unit: mm
Global Coordinate System
Time: 1
09/04/2020 19:06

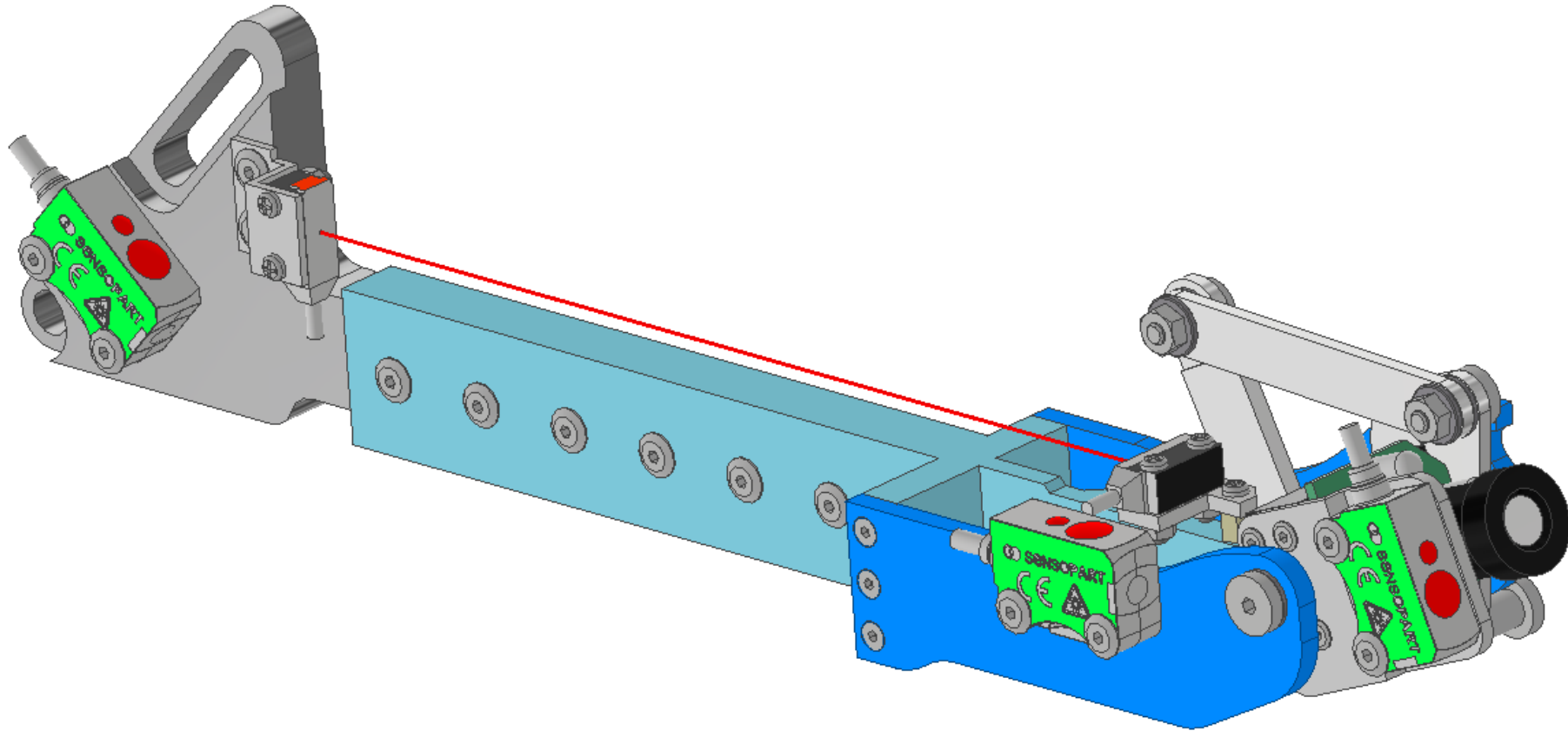


FEM Results → Max vertical displacement = 4.3 mm

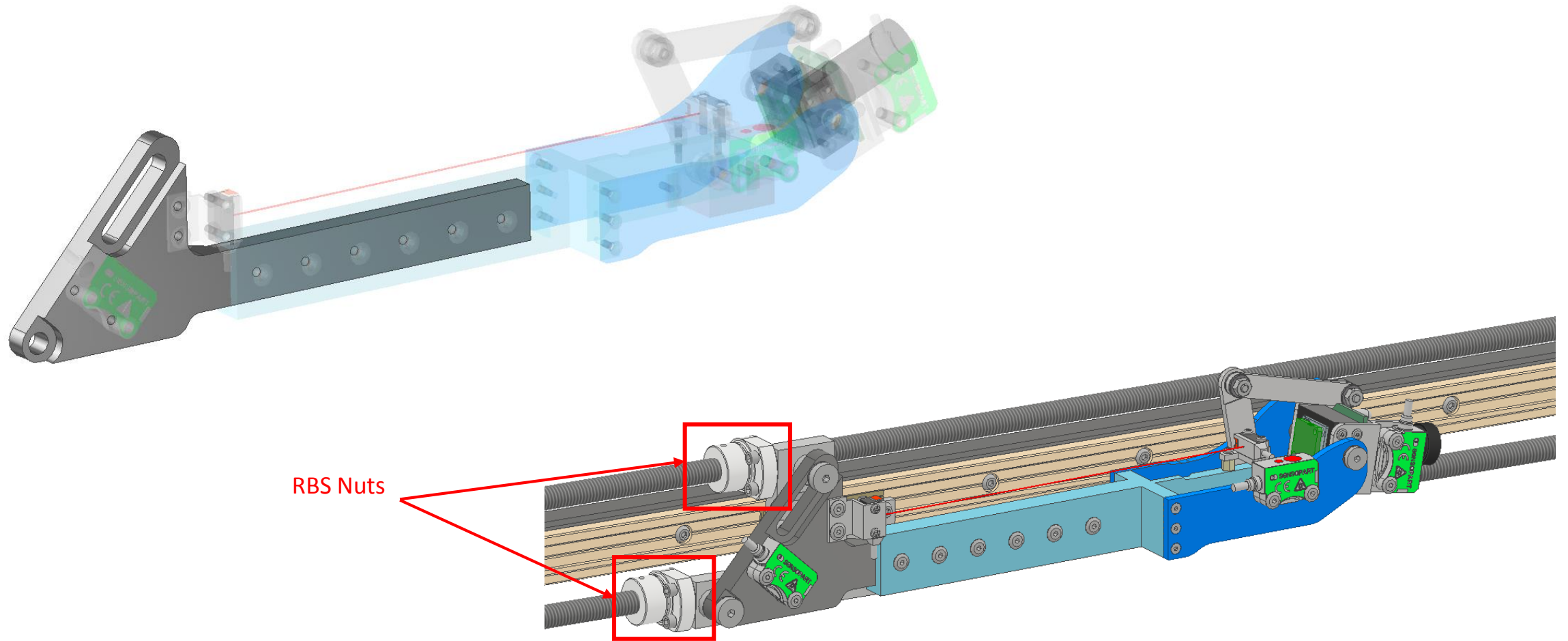


Robotic Arm

Sensorized 3 DOF Extensible Robotic Arm

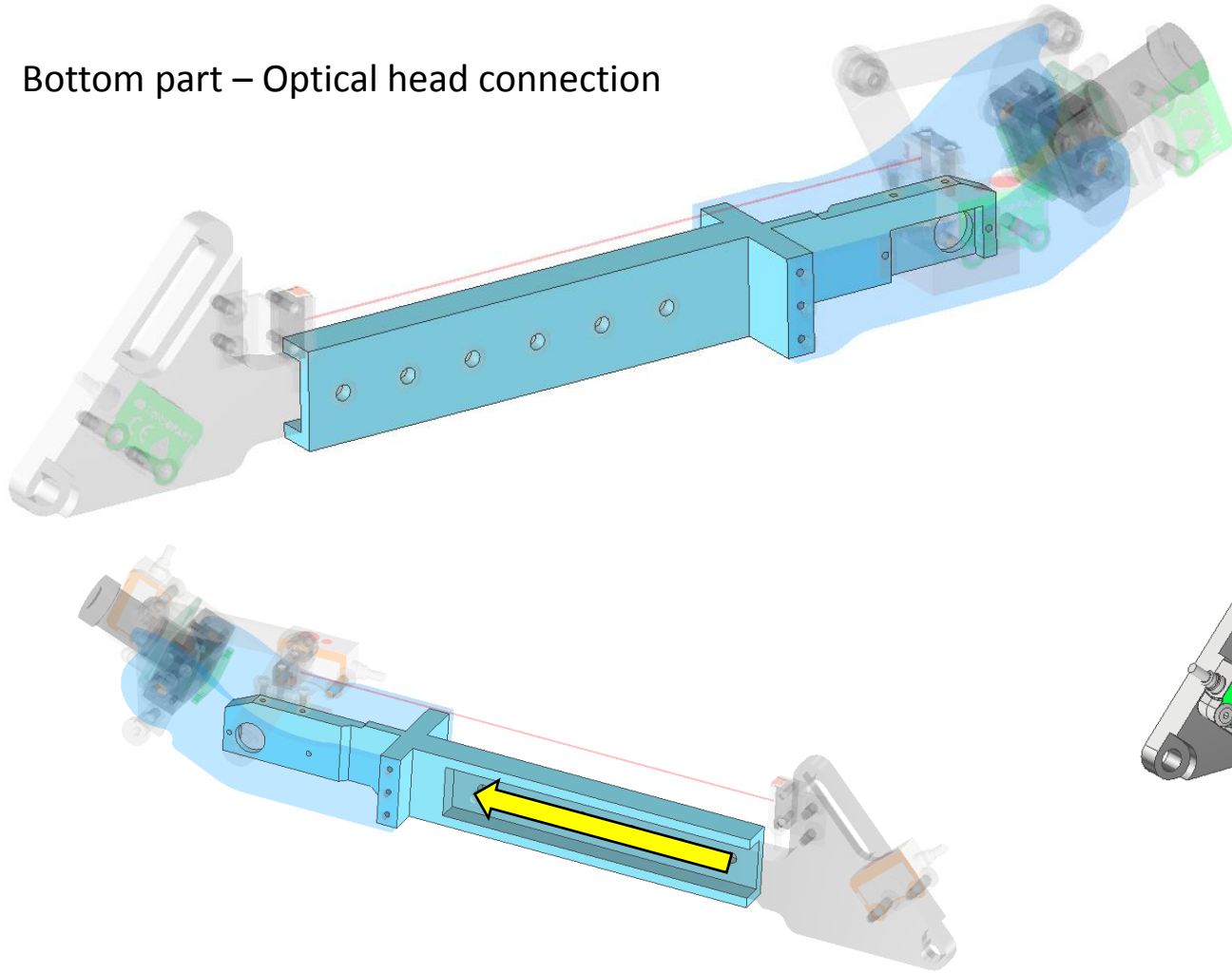


Robotic Arm → Mechanical Components → **Arm Bottom part**

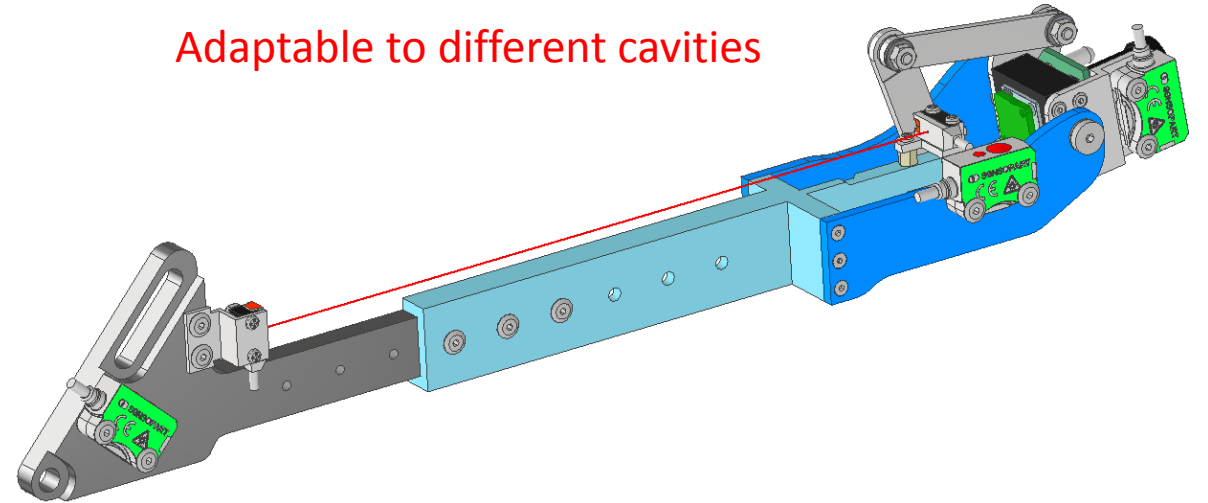


Robotic Arm → Mechanical Components → Arm Top Extensible part

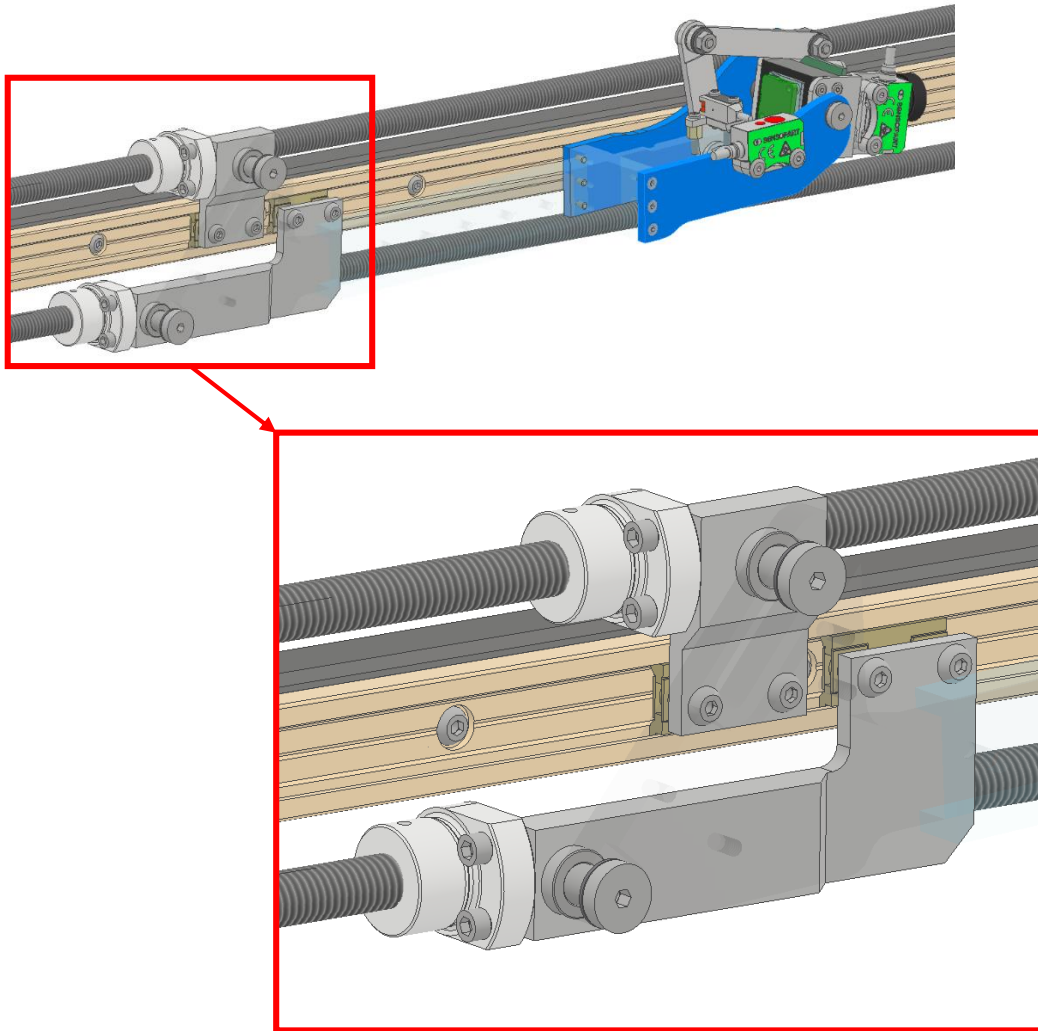
Bottom part – Optical head connection



Adaptable to different cavities



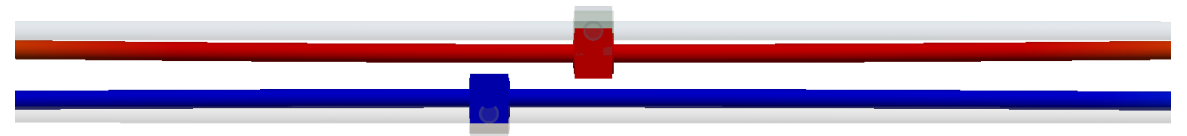
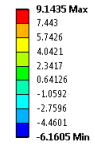
Robotic Arm → Mechanical Components → Arm – Rail Connection



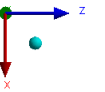
FEM Results → Max displacement = 9 mm

FEM Results → Max displacement = 6 mm

D: Ball Screw Inflexion
Directional Deformation 4
Type: Directional Deformation(X Axis)
Unit: mm
Global Coordinate System
Time: 1
04/10/2019 13:55

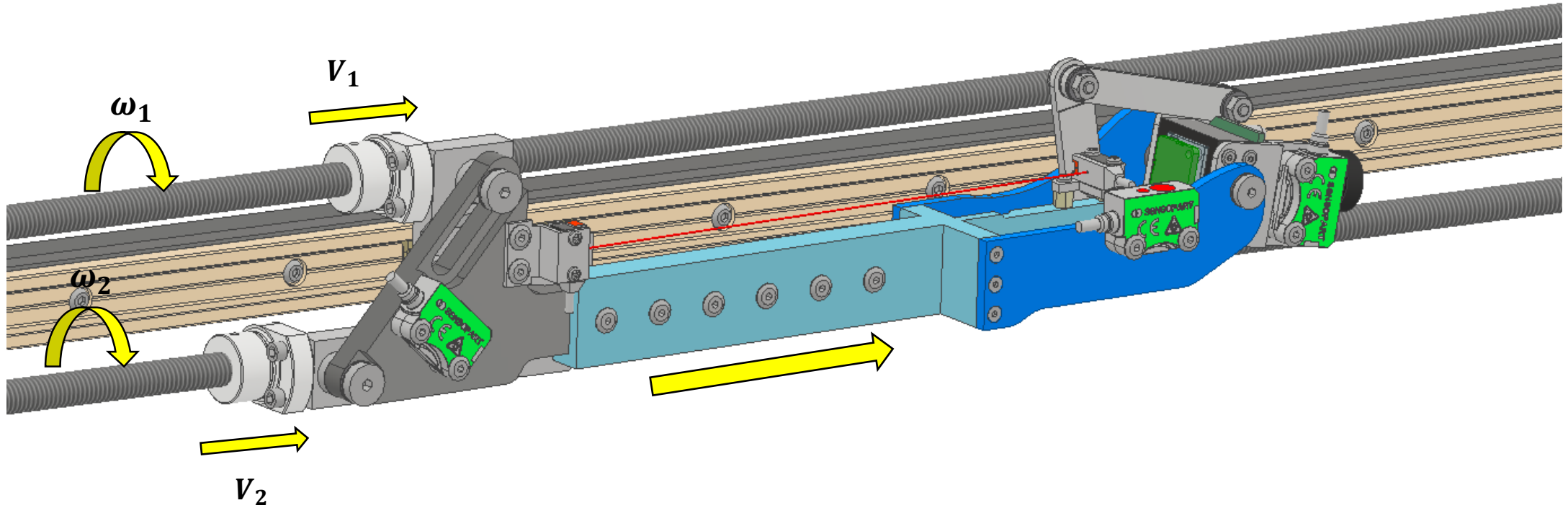


0.00 25.00 50.00 75.00 100.00 (mm)



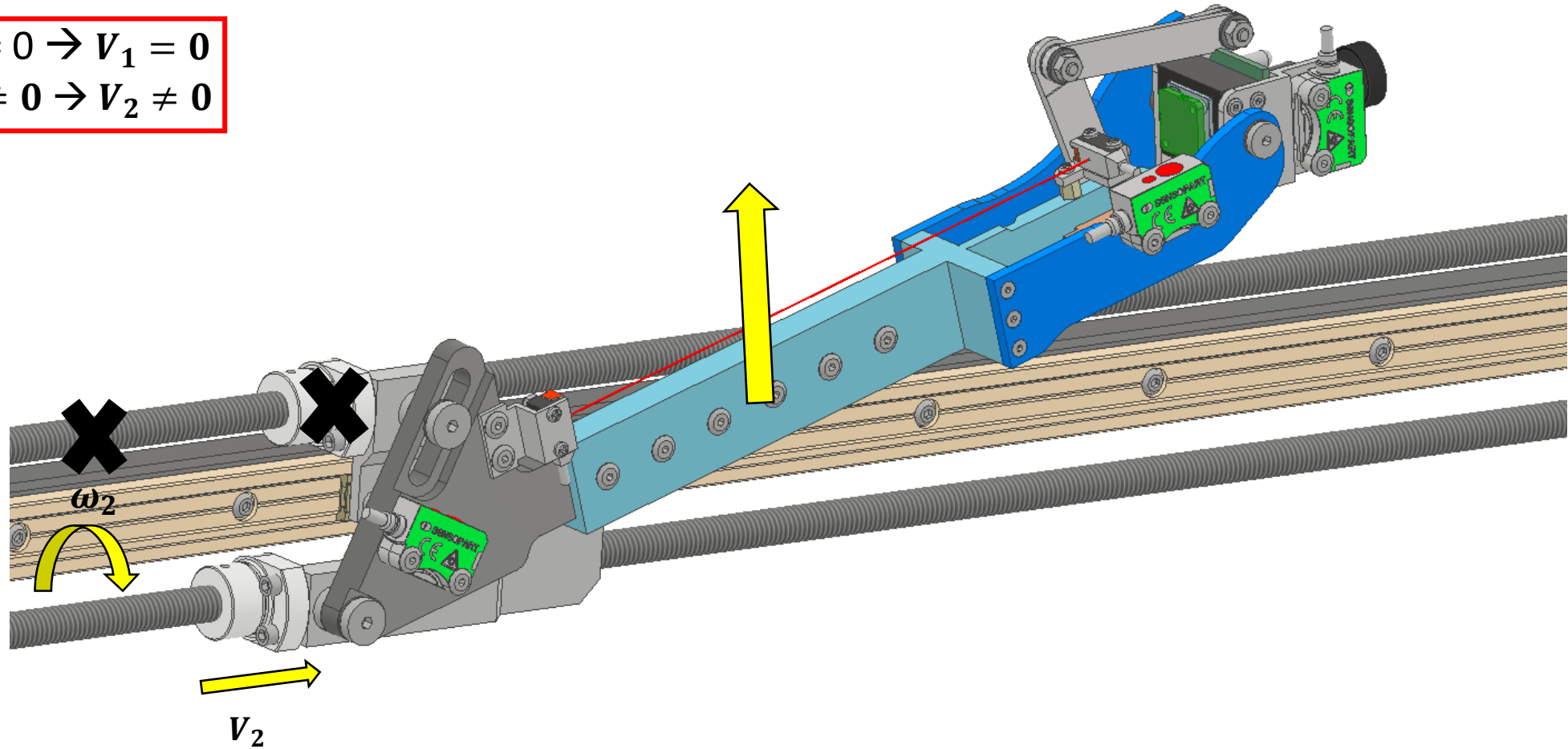
Robotic Arm \rightarrow Kinematics \rightarrow Linear Motion (Axial reachability)

$$\omega_1 = \omega_2 \rightarrow V_1 = V_2$$

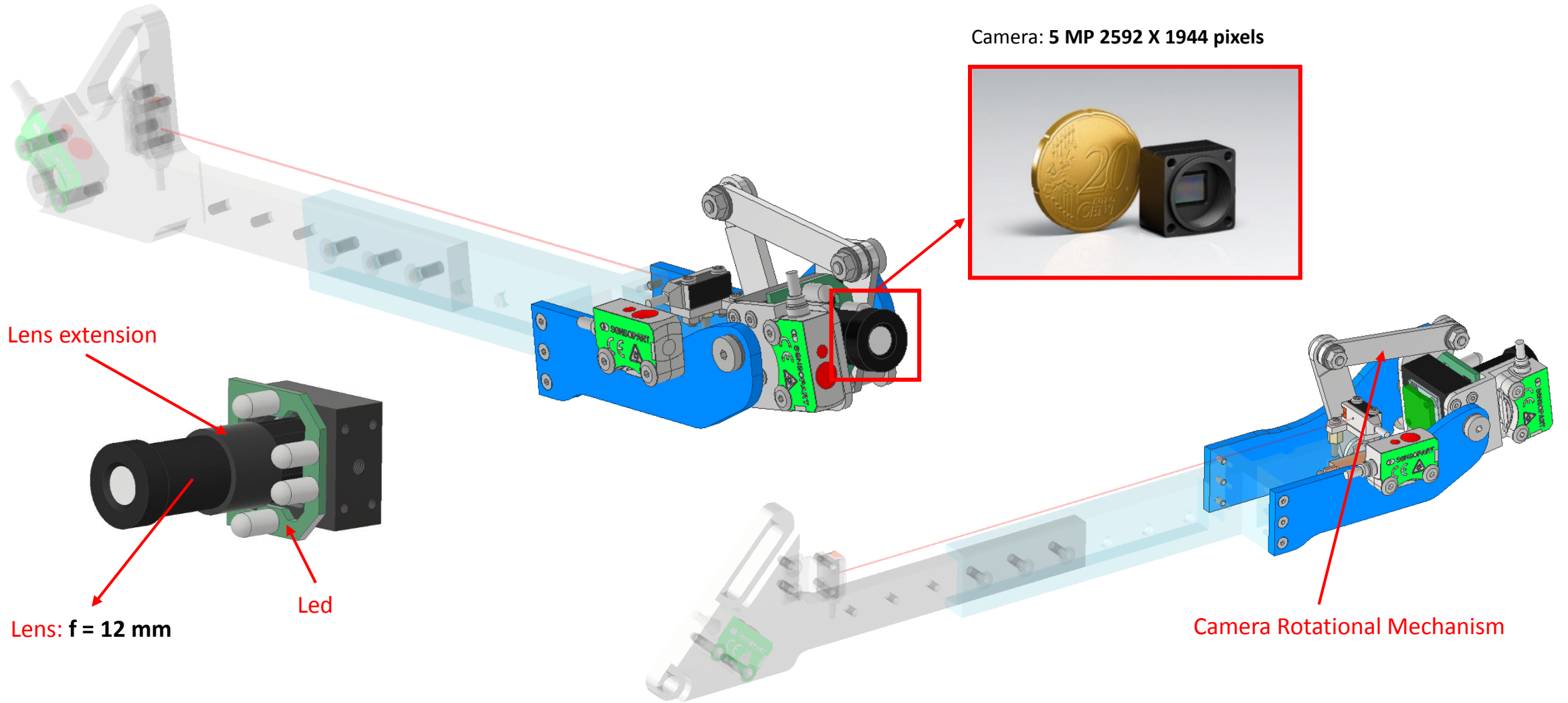


Robotic Arm → Kinematics → Rotation (Vertical reachability)

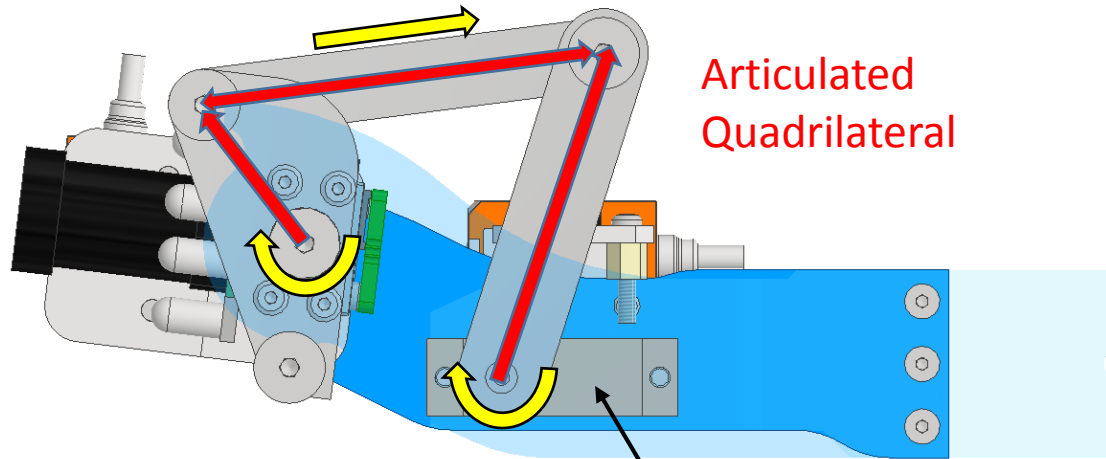
$$\omega_1 = 0 \rightarrow V_1 = 0$$
$$\omega_2 \neq 0 \rightarrow V_2 \neq 0$$



Robotic Arm → Mechanical Components → Optical Head

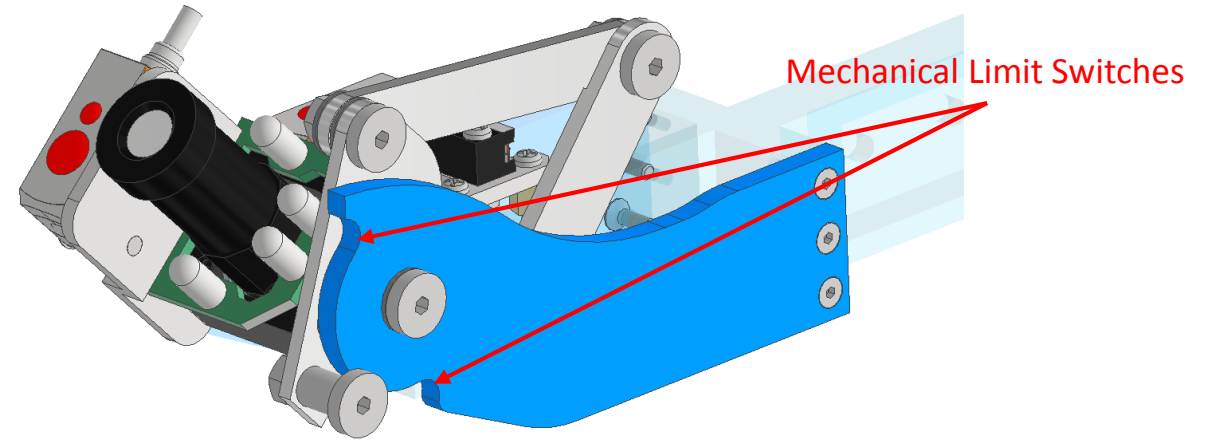


Robotic Arm → Mechanical Components → Camera Rotational Mechanism

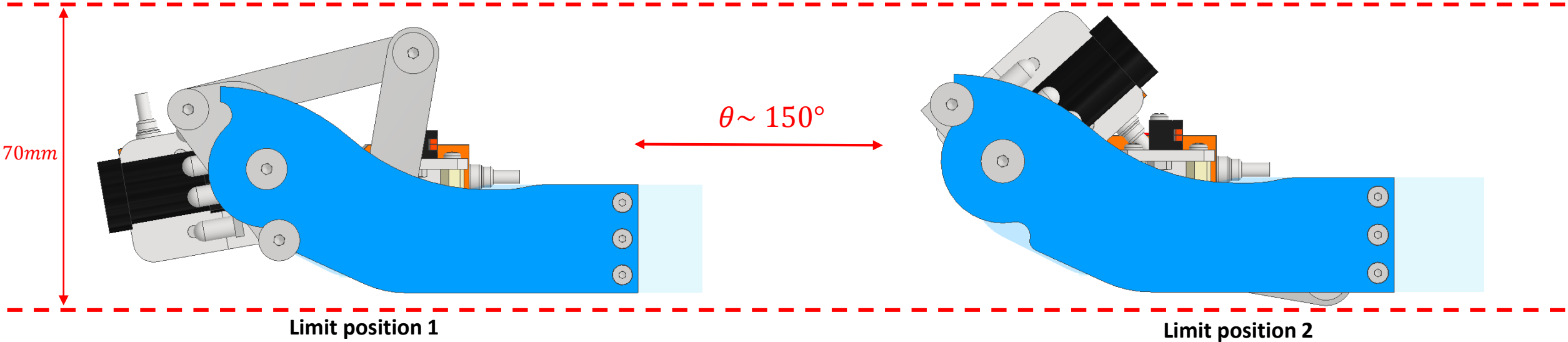


Articulated
Quadrilateral

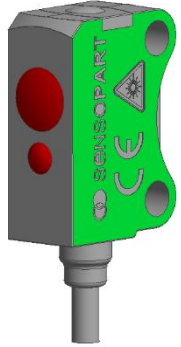
Nano Servo-Motor



Mechanical Limit Switches

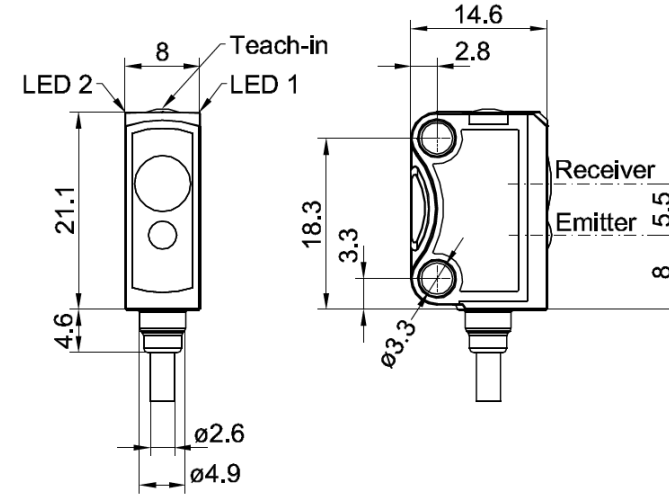


Robotic Arm → Anti-collision Sensors



Sub-miniature laser distance sensor (Sensopart FT 10-RLA)

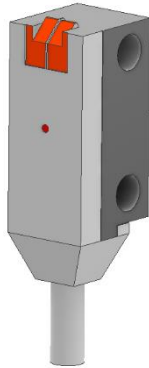
- Measurement range: 10...70 mm
- Resolution: 13 bit via IO-Link
- Repeatability: < 0.1 mm (at 40 mm)
- Light spot size: 1 x 3 mm
- Response time: 500 μ s



Emitter

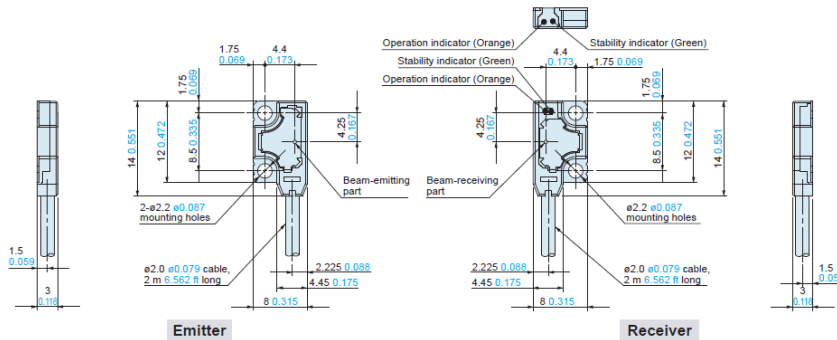


Receiver

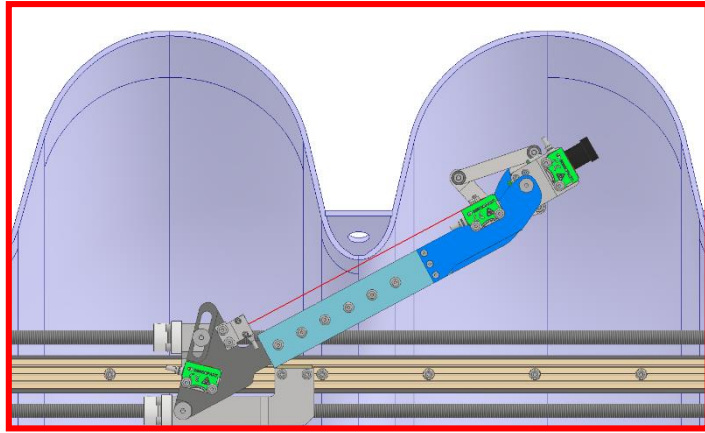


Ultra-minute Photoelectric Sensor (Panasonic EX-Z13B-P)

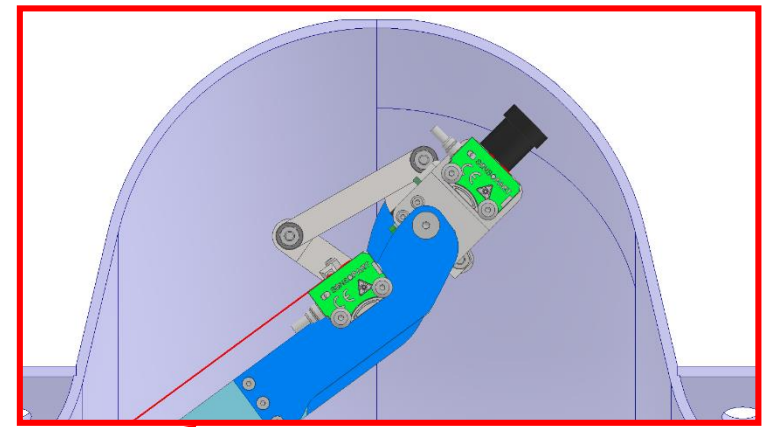
- Sensing range: 500 mm
- Repeatability: 0.05 mm
- Minimum sensing object: $\phi 1$ mm



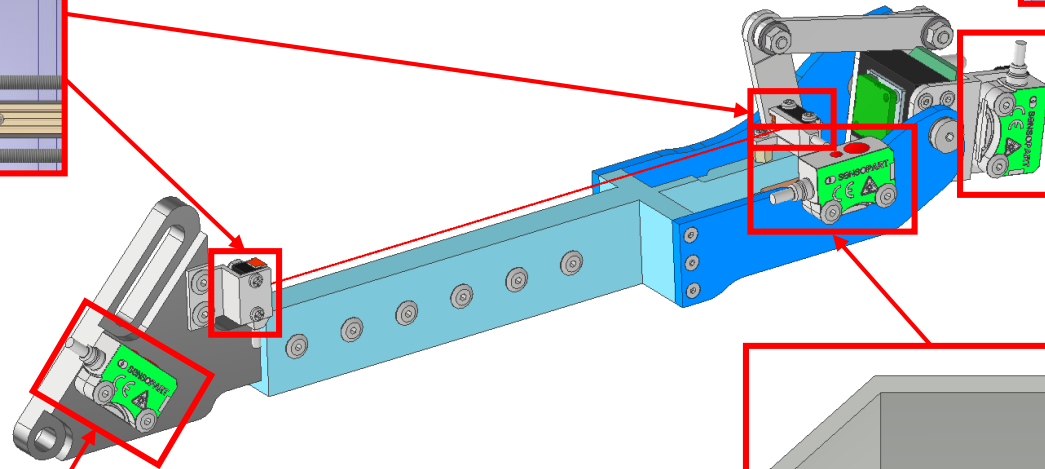
Robotic Arm → Anti-collision Sensors



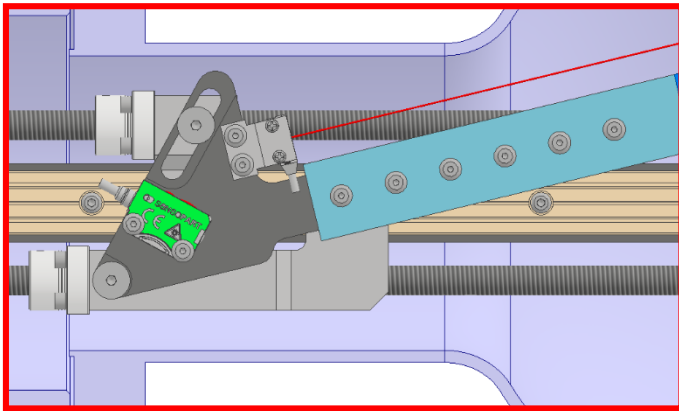
Shaft collision at iris zone



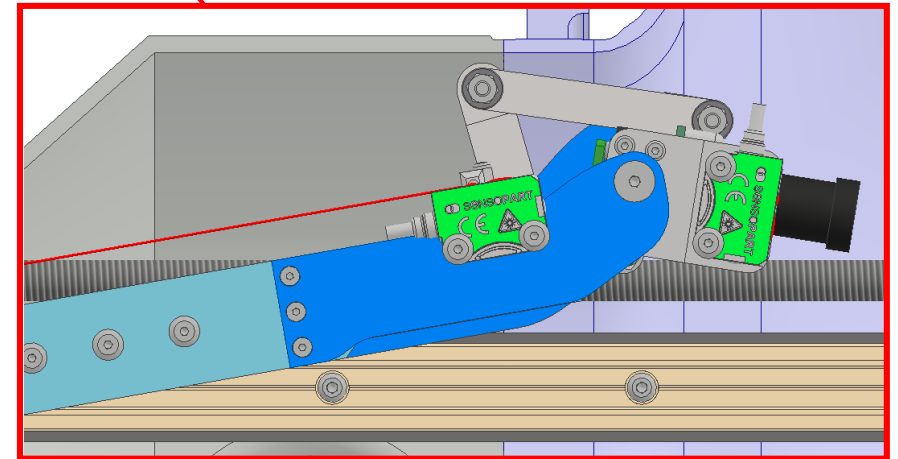
Camera collision and focus



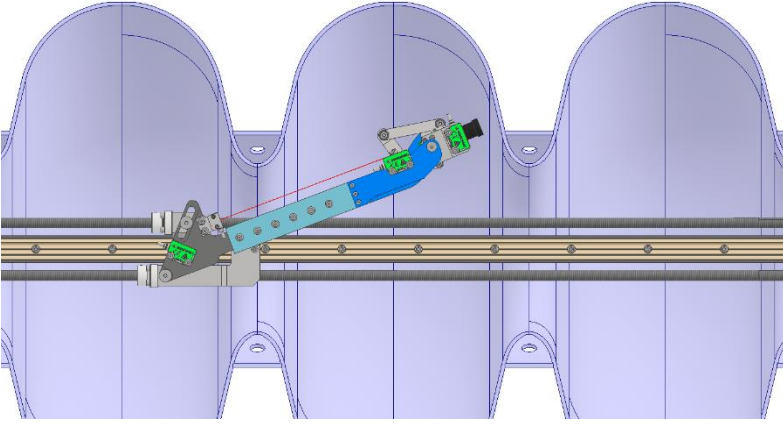
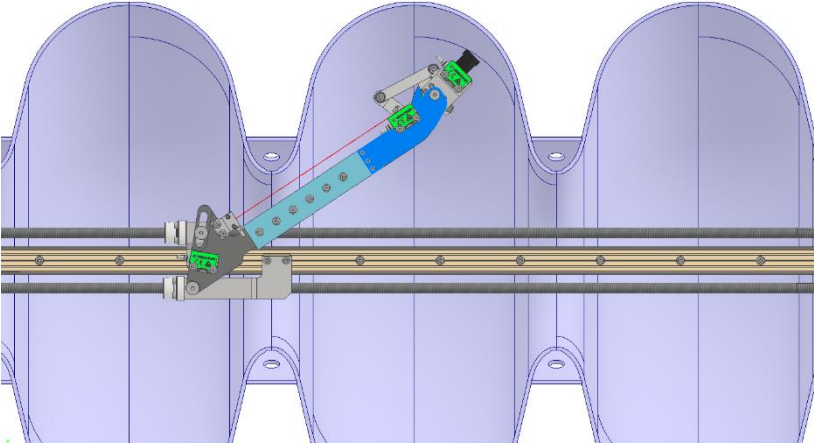
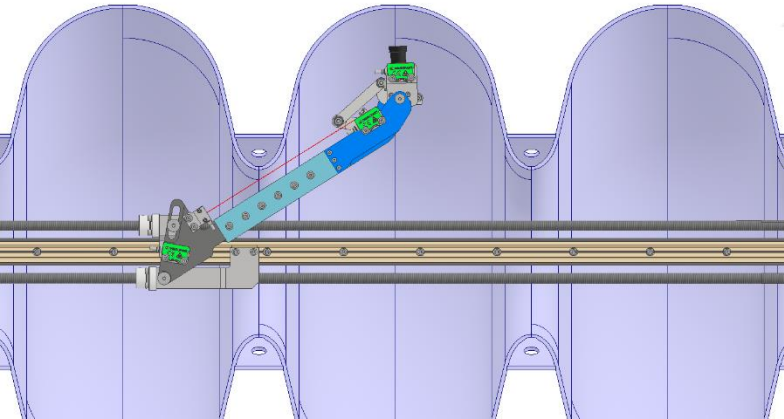
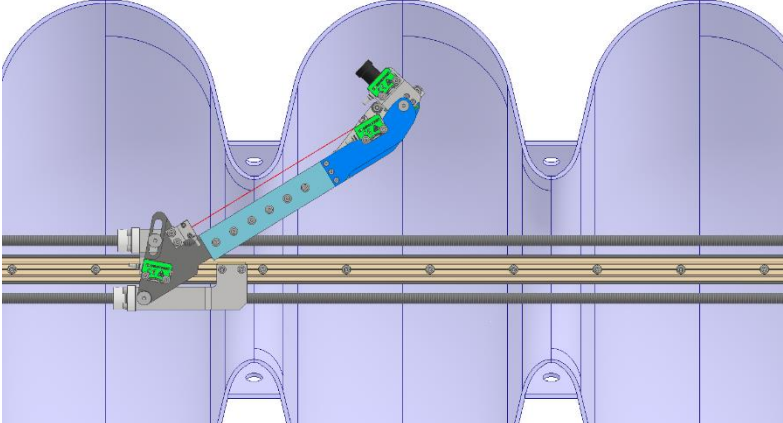
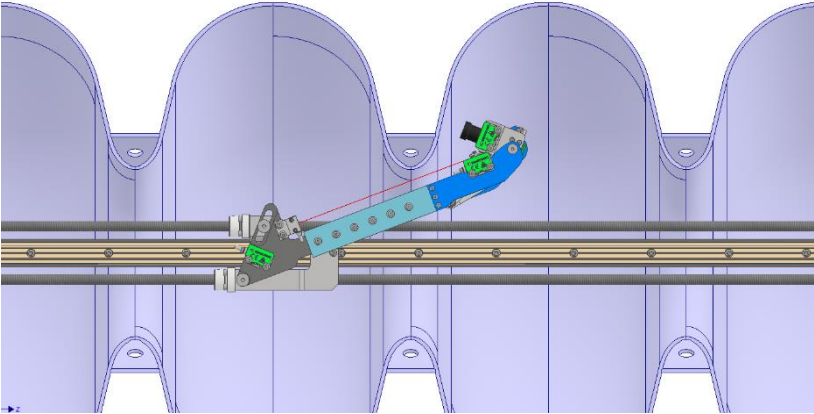
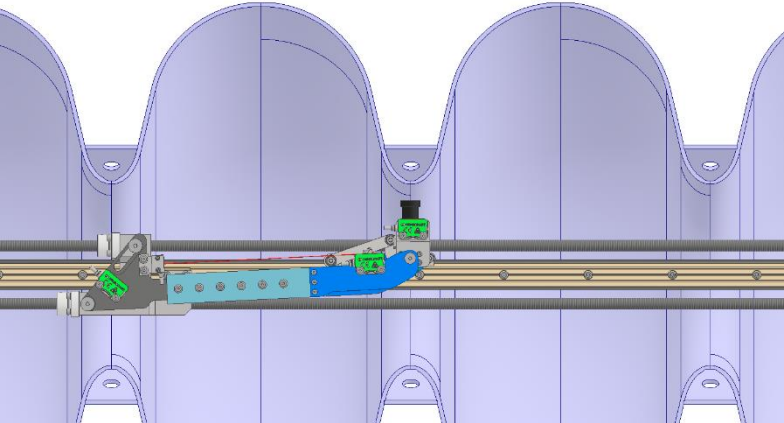
Collision of the botton-hole in 1.3 GHZ



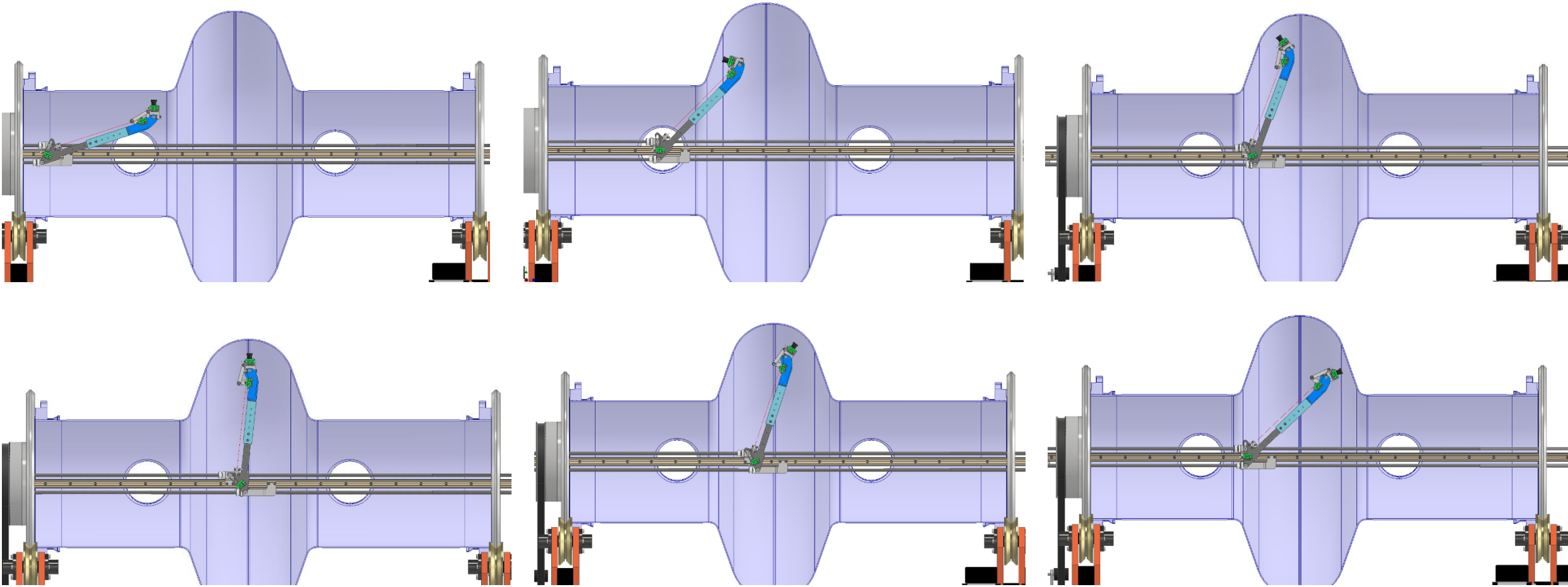
Crank collision



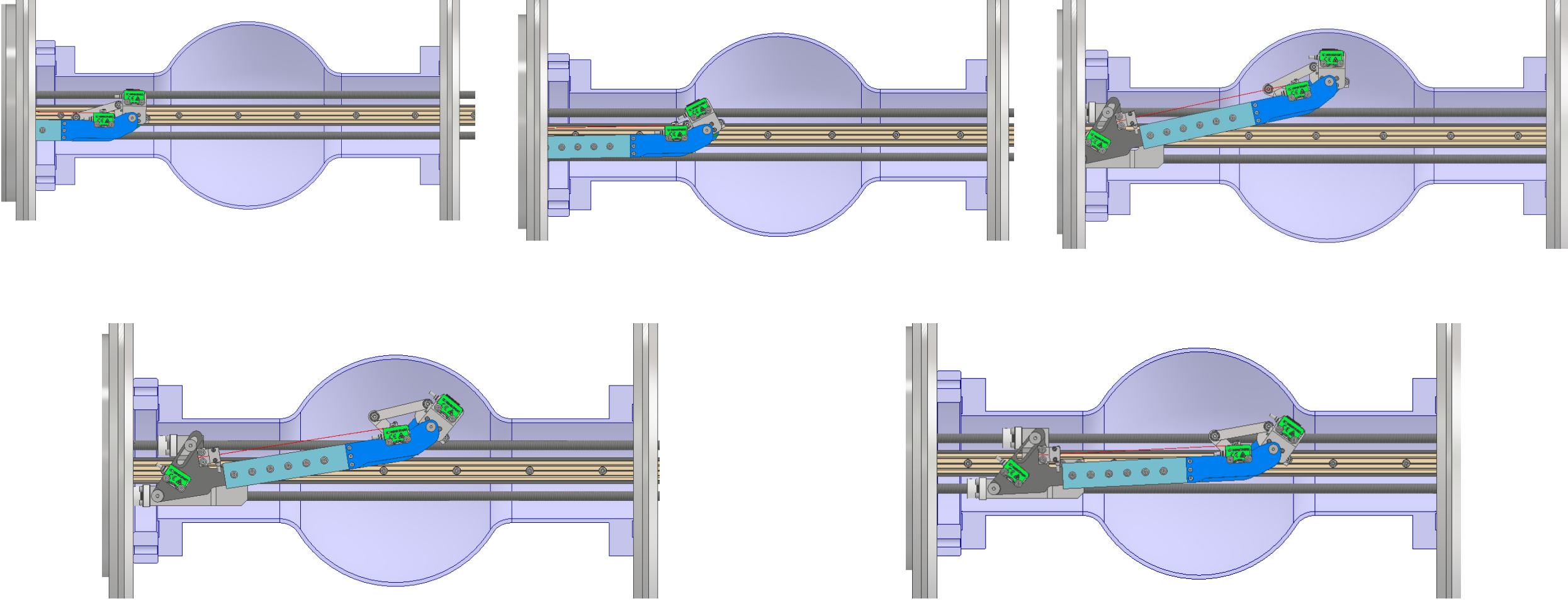
Virtual Inspection Test → High Gradient 5-Cells Cavity



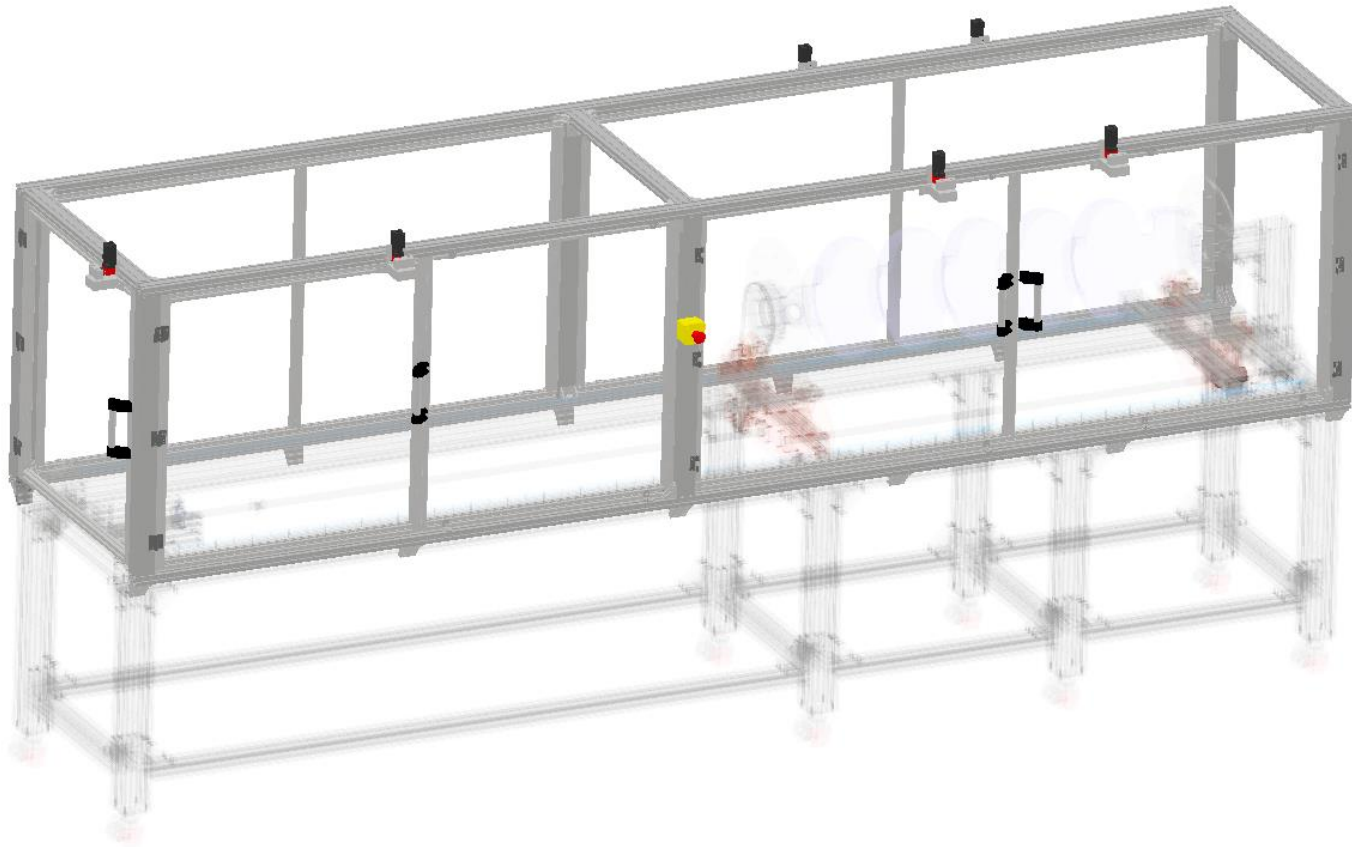
Virtual Inspection Test → LHC Single-Cell Cavity



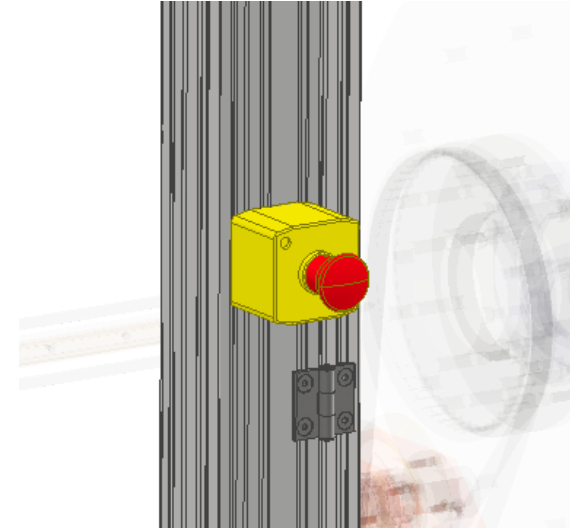
Virtual Inspection Test → 1.3 GHz Cavity



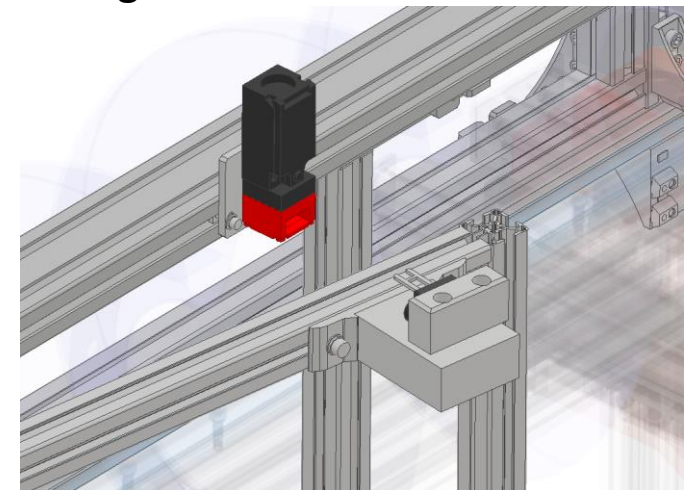
Safety Cage



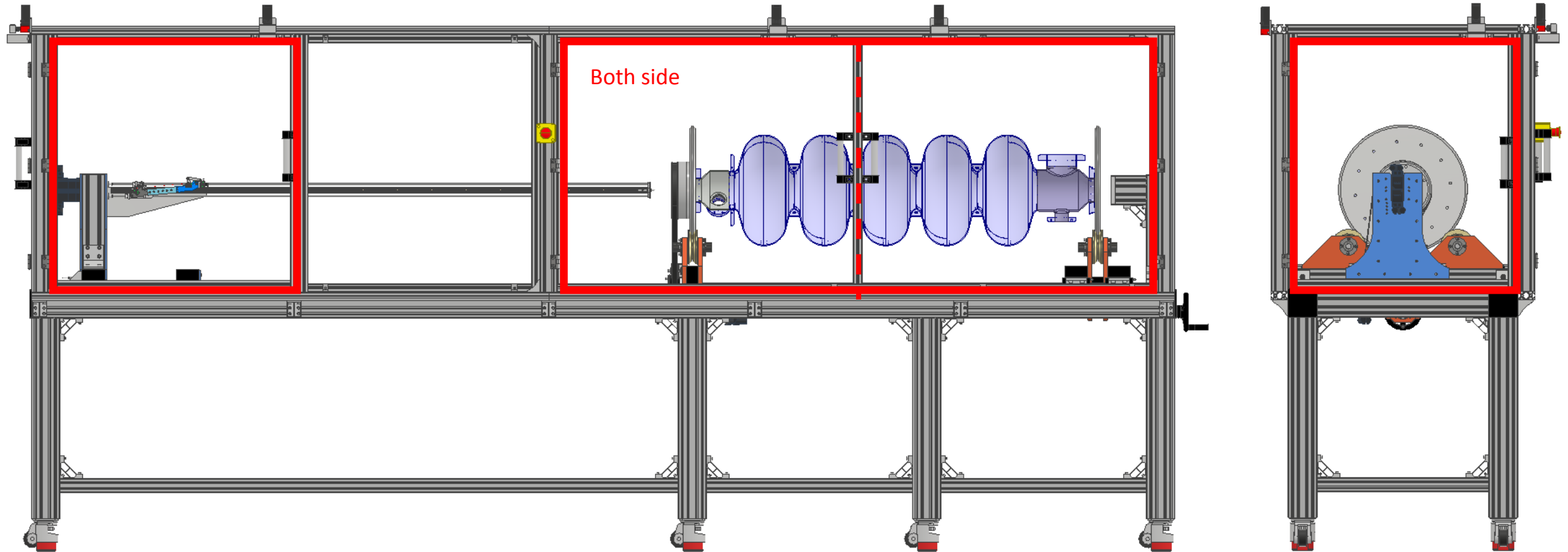
Emergency button



Closing switch



Safety Cage (first concept)



Outlooks

- System assembly
 - The greatest part of the commercial pieces are already in 628
 - Parts to be machined
- Actuator purchase and installation
- Test phase
- Control software
- Machine Learning-based defect detection
- Application services (e.g. GUI, database, notifications etc.)